

FREQUENCIES OF TROPICAL CYCLONES, ESPECIALLY THOSE OF MINOR IMPORTANCE

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Most discussions of tropical cyclones are confined to severe storms because of the common emphasis on the damage done. Indeed, often all but the most destructive storms, or those with hurricane winds, are ignored by meteorologists. In recent years, however, it has been increasingly recognized that even the most severe storms commence as mere slight depressions. Furthermore, even tropical barometric depressions which are too shallow to induce much wind often yield much rainfall. Although shipping has, in general, little interest in rainfall and conditions producing it, unless strong winds occur therewith, people on the land take a different attitude toward depressions which yield rainfall and other changes of weather.

Information concerning minor tropical cyclones, depressions, or lows has become recently much more abundant, especially within areas which are now included in synoptic daily weather maps.

As one phase of a study of the effects of tropical cyclones, consideration has been given to the question of how many tropical disturbances enter mid-latitudes and affect the weather there. A preliminary article on this subject may be found in the *Geographical Review* of January, 1925 (5). In continuation of that study, more recent records have been examined, including the daily weather maps of India, the North Pacific, and Brazil.

Table I gives the average number of tropical cyclones occurring yearly in certain areas, according to the indications of recent data. The three classifications refer to the intensity of the disturbances. Hurricanes are storms which for a part of their existence were known to have been accompanied by winds of 75 miles an hour or more; gales are tropical cyclones which had some winds of gale force (32 to 75 miles per hour). Lows are distinct depressions with at least feeble cyclonic circulation, but without winds of more than 32 miles an hour, except in the thunderstorm squalls, perhaps.

TABLE I.—*Frequencies of tropical cyclones in various areas*
[Approximate number occurring in an average year recently]

| | Hurricanes | Gales | Lows |
|---|------------|-------|------|
| Western North Pacific (110° E. to 140° E.) | 10 | 18 | 30 |
| Central North Pacific (140° E. to 140° W.) | 2 | 4 | 7 |
| Eastern North Pacific (east of 140° W.) | 2 | 3 | 3 |
| South Pacific (160° E. to 130° W.) | 5 | 8 | 5 |
| Australia and coastal seas (110° E. to 160° E.) | 5 | 8 | 10 |
| South Indian Ocean | 8 | 5 | ? |
| Arabian Sea | 2 | 2 | 2 |
| Bay of Bengal | 2 | 4 | 15 |
| Western North Atlantic | 3 | 2 | 14 |

Many of the data upon which the figures for the tropical cyclones with winds of gale or hurricane force are based have been summarized in this journal (1-3) or elsewhere (4-8). The sources of the large figures for the lesser tropical disturbances or lows in several of the areas merit special mention here. For Australia the daily weather maps covering 30 years were studied, while the author was attached to the Central Meteorological Office, Melbourne (6).

The figures for the more severe storms of the Far East are summarized in (3) and (4). The sources of the figures for the minor disturbances are (a) the annual reports of the Central Meteorological Observatory of Japan, Tokyo, for the years 1905, 1907, 1914-1918, especially 1907, and (b) the weekly weather reports of the Imperial Marine Observatory, Kobe, for 1920, 1921, and 1922, and (c) the daily weather report of the North Pacific, discussed in the next paragraph (9). In the annual reports the tracks of the more distinct cyclones affecting Japan are given, and for 1907 also the tracks of all the minor barometric depressions or lows. In the weekly weather reports for 1920-1922 there are small daily maps and also weekly summaries of the cyclonic disturbances. The tracks, in these summaries and in the annual reports, commencing within 30° of the Equator were counted. (Latitude 30° is often considered as the margin of the tropics, as, for example, by Henry (14).) More than 100 tropical lows are plotted for 1907 and an average of over 70 for 1920-1922. Hence the figures here given, 30 minor, 28 stronger cyclones, seem decidedly conservative.

The daily weather reports of the North Pacific, of the Imperial Marine Observatory, Kobe, Japan, for 1923, 1926, 1927, and 1928 show an average of 51 tropical cyclones yearly in the Western North Pacific. (See Table 2.) More than 40 of these 51 are shown on the daily maps, however, to have been accompanied at least in part of their course by strong winds. In other words, the North Pacific maps reveal an average of more than 40 gale or hurricane producing tropical cyclones a year, during these four years, in the Far East, instead of the 28 given in Table 1. But these maps show relatively few of the more minor type of disturbance which were included in the more detailed reports for the Far East alone, referred to in the previous paragraph. Hence the first line of Table 1 is a conservative compromise between these two excellent Japanese sources of data (9).

The data for the Central North Pacific are from three chief sources—(a) the monthly accounts of cyclones in this region given in the *MONTHLY WEATHER REVIEW* by Hurd, in his section of the storms of the North Pacific Ocean in the monthly account on Weather of the Atlantic and Pacific Oceans. These accounts for six years were examined; (b) The Japanese Daily Weather Reports of the North Pacific, already referred to, for the four years 1923, 1926, 1927, and 1928. More than a third of the cyclones shown on these maps as originating east of 140° E. developed in longitudes 104° to 160° E. and moved into the Western Pacific. The others moved northward. A few storms, charted and discussed in (2, 8), entered the Central North Pacific, as here delimited, from the Eastern Pacific, but none such are shown on the Japanese maps, which do not in fact deal with the southeastern part of the North Pacific.

The figures for the frequency of hurricanes in the Central North Pacific is based partly on scattered accounts of violent storms in this region, summarized in (7).

TABLE 2.—Tropical cyclones shown in daily weather charts of the North Pacific, developing east of the Philippine Islands (125°–160° E.)

[Imperial Marine Observatory, Kobe]

| | 1923 | 1926 | 1927 | 1928 | Average |
|----------------|------|------|------|------|---------|
| January..... | | 1 | | 2 | 0.75 |
| February..... | | | 1 | | .25 |
| March..... | 1 | 1 | | 1 | .75 |
| April..... | | | | 1 | .25 |
| May..... | 1 | 1 | 1 | 3 | 1.5 |
| June..... | 2 | 2 | 2 | 1 | 1.75 |
| July..... | 3 | 4 | 3 | 3 | 3.25 |
| August..... | 7 | 4 | 3 | 3 | 4.5 |
| September..... | 4 | 5 | 3 | 4 | 4.0 |
| October..... | 2 | 3 | 4 | 3 | 3.25 |
| November..... | 2 | | 1 | 2 | 2.0 |
| December..... | | 1 | | 1 | 0.5 |
| Year..... | 22 | 26 | 19 | 24 | 22.75 |

TABLE 3.—Tropical cyclones developing north of the Philippines (18° N. to 30° N.)

[Imperial Marine Observatory charts]

| | 1923 | 1926 | 1927 | 1928 | Average |
|----------------|------|------|------|------|---------|
| January..... | 1 | | 3 | 2 | 1.5 |
| February..... | 4 | 3 | 4 | 3 | 3.5 |
| March..... | 3 | 5 | 4 | 4 | 4.0 |
| April..... | 6 | 2 | 4 | 3 | 3.75 |
| May..... | 1 | 2 | 2 | 2 | 1.75 |
| June..... | 3 | 1 | | 6 | 2.5 |
| July..... | 2 | | | 2 | 1.0 |
| August..... | 1 | | 1 | 1 | .75 |
| September..... | 3 | | 2 | 1 | 1.5 |
| October..... | | | 1 | | .25 |
| November..... | | | 1 | 3 | 1.0 |
| December..... | 1 | 2 | 2 | 2 | 1.75 |
| Year..... | 24 | 15 | 24 | 29 | 23.25 |

TABLE 4.—Tropical cyclones developing west of the Philippines¹

[Imperial Marine Observatory charts]

| | 1922 | 1926 | 1928 | Average |
|----------------|------|------|------|---------|
| January..... | | | 1 | 0.33 |
| February..... | 1 | | | .33 |
| March..... | 1 | | 1 | .66 |
| April..... | 1 | | | .33 |
| May..... | 2 | | | .66 |
| June..... | | 1 | 2 | 1.0 |
| July..... | | | 1 | .33 |
| August..... | 2 | | 1 | 1.0 |
| September..... | | | | |
| October..... | | | | |
| November..... | | | | |
| December..... | | 2 | | .66 |
| Year..... | 7 | 3 | 6 | 5.3 |

¹ 1922 from charts for the Western Pacific.TABLE 5.—Tropical cyclones developing in the Central North Pacific (140° E. to 140° W.)²

[Imperial Marine Observatory charts]

| | 1923 | 1926 | 1927 | 1928 | Average |
|----------------|------|------|------|------|---------|
| January..... | 2 | 1 | 3 | | 1.5 |
| February..... | 2 | | | 1 | .75 |
| March..... | 2 | | 3 | 2 | 1.75 |
| April..... | | | 2 | 1 | .75 |
| May..... | | 1 | | 1 | .5 |
| June..... | | | | | |
| July..... | 2 | | 1 | 1 | .5 |
| August..... | 2 | 1 | 1 | 1 | 1.25 |
| September..... | 1 | 1 | 3 | 4 | 2.25 |
| October..... | 1 | 1 | 4 | 1 | 1.75 |
| November..... | | 1 | 2 | 2 | 1.25 |
| December..... | 1 | 1 | 2 | | 1.0 |
| Year..... | 13 | 7 | 21 | 14 | 13.25 |

² About one-third of these develop 140° to 160° E.

The figures for the Eastern North Pacific were obtained from sources already mentioned (2), supplemented by Hurd's summary of the storminess of this region in recent years (11). This includes storms reported by the Mexican Weather Bureau but not mentioned hitherto in the MONTHLY WEATHER REVIEW. The figures for the minor disturbances is an approximation based on accounts of abnormal wind conditions in this area. Hurd in his monthly accounts in the REVIEW mentions many minor disturbances reported by ships, which he does not include among his list of the storms of the year.

The figures for the South Pacific are based on personal studies of conditions in Fiji and other island groups (1, 4, 12). Weather changes in Fiji, revealed by the daily meteorological conditions for four years, suggest that several minor tropical depressions affect Fiji each year on the average (12).

The figures as to the severe tropical cyclones in the Western North Atlantic are from Mitchell and Henry (13, 14). The minor cyclonic disturbances are, however, not discussed by Mitchell, Henry, or other writers. Mitchell informs me that the weather maps of the West Indian region (not published) reveal an average of only two tropical cyclones a year which have well-developed cyclonic winds but which do not attain winds of gale force. In addition there are, he reports, a considerable number of tropical LOWS (westward moving areas of falling pressure) which do not have well-developed cyclonic circulation but which often cause much rainfall. Mitchell has not determined the average frequency of such LOWS. Hence their frequency was estimated from the number of LOWS charted by W. P. Day and others as affecting the United States each month (MONTHLY WEATHER REVIEW, Charts II and III). In the REVIEW for 1922 Day states that LOWS of the Texan, Gulf, and South Atlantic types had an average frequency during the 21 years 1892–1912 of 19 per year. During the 10 years 1919–1928 there are plotted the tracks of an average of 22.1 LOWS entering the United States from the south or passing northward near the Atlantic coast. The moderate increase shown during the last decade may reflect fuller reports, including radio reports. Since a considerable number of minor tropical cyclones do not pass northward near enough to affect the United States to merit their being shown on the daily weather maps of that country, the estimate given as the final figure in Table 1 seems conservative.

The figures for the more intense storms of the Bay of Bengal and the Arabian Sea are from Newnham (15) and Normand (16, 17). The frequency of the minor disturbances is not obtainable from Normand's atlases, however, as he specifically states that the atlas of the Bay of Bengal omits many of the numerous slight storms of the monsoon season, June to September. Newnham mentions an average of six depressions a year for the period 1900 to 1912, but the fuller reports from ships since the use of the radio has become general has more than doubled this figure. The daily weather reports for 49 months—July, 1924, to July, 1929, inclusive, except 1928—have been examined and reveal an average of about 21 tropical cyclones a year, of which, 2 a year on the average are called in the weather reports severe storms or hurricanes and 3 or 4 are called storms. The remaining 15 or 16 are called depressions or, rarely, disturbances. Table 6 gives the occurrences of these tropical cyclones for the months studied.

TABLE 6.—Tropical cyclones of the Bay of Bengal, depressions, and storms

[Indian Daily Weather Reports]

| | 1924 | 1925 | 1926 | 1927 | 1929 | Average |
|----------------|------|------|------|------|------|---------|
| January..... | (1) | | | | 1 | 0.5 |
| February..... | | 1 | | | | |
| March..... | | 1 | 1 | | | .5 |
| April..... | | 2 | 3 | | | 2.0 |
| May..... | | 2 | 3 | 2 | 1 | 2.75 |
| June..... | | 1 | 6 | 2 | 2 | 3.4 |
| July..... | 1 | 3 | 5 | 5 | 5 | 3.5 |
| August..... | 4 | 2 | 5 | 3 | | 3.0 |
| September..... | 3 | 2 | 4 | 3 | | 2.25 |
| October..... | 2 | 2 | 3 | 2 | | 1.75 |
| November..... | 2 | 3 | 2 | | | 1.75 |
| December..... | | 2 | 1 | | | 0.75 |
| Year..... | | 21 | 29 | 17 | | 21.15 |

¹ Maps for first half of 1924 not studied.² Data for balance of 1929 not yet received here at date of compilation.

Only the eastern part of the Arabian Sea is included in the Indian Daily Weather Map and Report, and hence Table 7 does not include all of the tropical cyclones of that sea during the 49 months studied. Of the 4 to 8 storms and depressions shown per year in Table 7, from 1 to 3 a year entered the Arabian Sea from the Bay of Bengal. An average of about 4 tropical cyclones and depressions developed annually in the eastern part of the Arabian Sea during the period studied.

TABLE 7.—*Tropical cyclones of the eastern Arabian Sea, depressions, and storms*

(Indian Daily Weather Reports)

| | 1924 | 1925 | 1926 | 1927 | 1929 | Average |
|----------------|------|------|------|------|------|---------|
| January..... | 1 | 1 | | | | 0.25 |
| February..... | | | | | | .0 |
| March..... | | | | | | .0 |
| April..... | | | 1 | | | .25 |
| May..... | | 2 | | 1 | | .75 |
| June..... | | 2 | | | 1 | .75 |
| July..... | | | 1 | 1 | | .5 |
| August..... | 1 | | 1 | | (?) | .5 |
| September..... | | | 2 | 1 | | .75 |
| October..... | | 1 | 1 | | | .5 |
| November..... | | 1 | | 1 | | (0.5) |
| December..... | 1 | 1 | | | | .5 |
| Year..... | | 8 | 6 | 4 | | 0.52 |

¹ Formed in Bay of Bengal.

² See notes at bottom of Table 6.

In a well-known official monograph on tropical cyclones published in 1913 it is stated that there are in the world an average of 34 tropical cyclones a year. The evidence summed up in Table 1 indicates, however, that there is instead, in the regions indicated, an average of more than 90 hurricane or gale-producing tropical cyclones annually, and probably even more lesser disturbances.

Although few tropical cyclones have violent winds over a belt wider than a few score miles across, the average tropical cyclone affects the weather over a much wider belt. Even slight disturbances of the lower air often lead to convectional overturning and thunderstorms. The daily weather reports of India, for example, repeatedly credit tropical cyclonic disturbances with producing rainfall far beyond their area of inclosed isobars and cyclonic winds. Cyclones also frequently cause a widespread change in the velocity of the general winds. For example, in India the monsoon is often reported by the official forecaster to have been strengthened over a wide area on one side of a cyclonic disturbance and weakened on the opposite side, with significant effects on the amount of rainfall. Correspondingly the orographical rainfall of Hawaii, Porto Rico, and other mountainous tropical areas is very greatly influenced by even weak or remote cyclonic disturbances which strengthen or weaken the ascending winds, depending on the position of the disturbance. Accompanying even moderate changes in wind velocity are often pronounced differences in convectional overturning and hence in rainfall. Except on the slopes of the higher tropical mountains, winds which merely slowly ascend the mountains cause little rainfall as compared with those slightly stronger winds in which convectional overturning occurs.

Evidences of frequent changes of weather in tropical localities is readily obtainable, but appears to have been largely ignored, partly because they were not supposed by leading meteorologists and climatologists to exist, at

least to a significant degree. Even Hann stated that in the Tropics one day is almost identically like the next. This is often true if minor changes are ignored, or in comparison to the more changeable regions of the world. But the changes of weather are significant in many places where agriculture is carried on extensively, because changes in rainfall are common. They are also significant in increasing an understanding of atmospheric circulation. When an attempt is made to discover the causes of the changes of weather of tropical localities evidence of many minor tropical cyclonic disturbances is disclosed and the effects of severe storms are seen to reach much farther than had been realized. Also it is discovered that many mid-latitude HIGHS affect tropical weather and that quite frequently in winter mid-latitude lows enter Tropics (18).

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